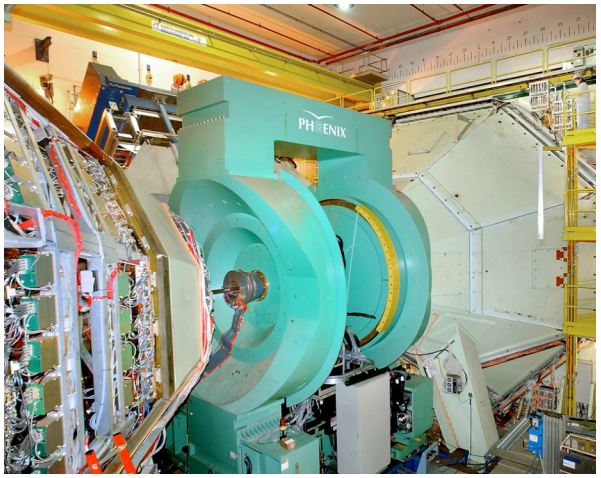
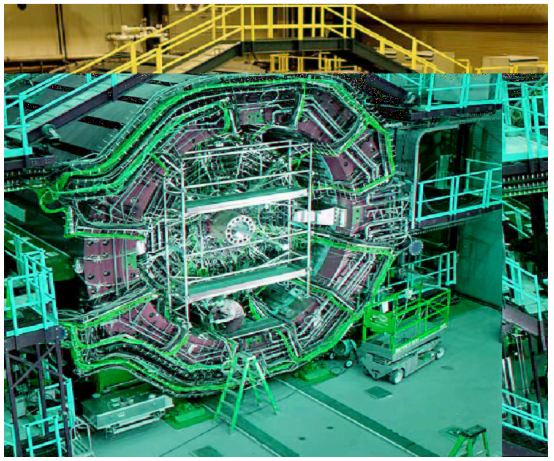
S&T Review
July 2009

Ed O'Brien

Brookhaven National Lab

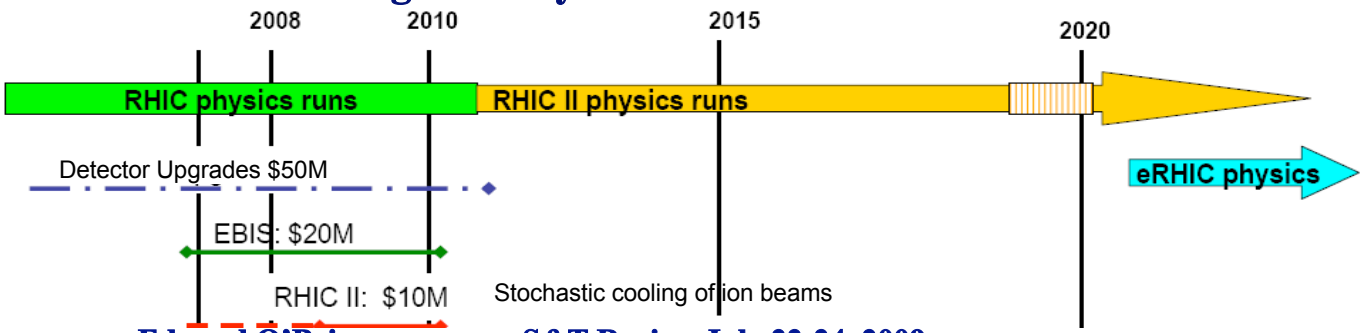
RHIC Detector Upgrades Projects





Upgrades plans for PHENIX and STAR give the experiments capabilities necessary to exploit the physics opportunities in RHIC's second decade of operation

- **Detailed studies of open heavy flavor characteristics in HI collisions**
- **Jet behavior/modification in sQGP medium**
- **e+e- continuum**
- **500 GeV p+p running for W-parity sea quark spin: u, u-bar, d, d-bar**
- **Low energy scan to search for QCD critical point**
- **Gluon saturation at low x and high density**



Upgrades to PHENIX and STAR

Additional capabilities are needed in both experiments as RHIC program:

- Detailed studies of open heavy flavor characteristics in HI collisions
- Jet behavior/modification in sQGP medium
- e+e- continuum
- 500 GeV p+p running for W-parity sea quark spin: u, u-bar, d, d-bar
- Low energy scan to search for QCD critical point
- Saturation effects at low x and high gluon density

New detector subsystems

- **Silicon vertex detectors (pixel, pads and strips)**
  - PHENIX Si barrel 2011, Si Endcaps 2012 (VTX, FVTX)
  - STAR Si barrel 2013 (HFT)
- **Forward W (single lepton) tracking/triggering devices**
  - PHENIX Resistive Plate Chambers + new LVL1 trig electronics 2011 (MuTrg)
  - STAR Forward multilayer GEM spectrometer 2011 (FGT)
- **Particle ID detectors**
  - STAR mRPC barrel Time of Flight 2009 (TOF)
  - PHENIX Hadron Blind Detector (GEM-based proximity-focused Cherenkov) 2009 (HBD)
- **Forward Calorimetery**
  - STAR Pb-Glass array $2.5 < \eta < 4.0$ 2008 (FMS)
  - PHENIX Si-tungsten array $1.5 < \eta < 3.0$ 2013, $PbWO_4$ array $3.0 < \eta < 4.0$ 2008 (FOCAL, MPC)
- **General DAQ/Trigger Upgrades (STAR DAQ1000, PHENIX DAQTRIG2010)**

RHIC Detector Upgrades

- **10+ subsystem upgrades**
- **Installed over 5-6 years**
- **~ $50M integrated over all projects (including R&D)**
- **A variety of funding sources including DOE, NSF, Japan, China, France, Russia, Korea…**

Year is installation/commissioning year of main detector components

Year	PHENIX	STAR
2008	Muon Piston Calorimeter (**MPC**)	Forward Meson Spectrometer (**FMS**)
2009	Hadron Blind Detector (**HBD**)	Time of Flight (**TOF**), **DAQ1000**
2010	MuTrigger-S arm (**MuTrg**)	
2011	Silicon Vertex Barrel (**VTX**), **MuTrg**-N arm	
2012	Forward Silicon Vertex Endcap (**FVTX**)	Forward GEM Tracker (**FGT**)
2013	Forward Calorimeter (**FOCAL**)**	Heavy Flavor Tracker (**HFT**) *

*** CD-0 approval, ** start pending science and project scope review**

Funding of RHIC Detector Upgrades

Projects Completed or Under construction

PHENIX MPC	Japan, Russia, DOE Cap Equip
STAR FMS	DOE Cap Equip
PHENIX HBD	DOE Cap Equip, NSF, Israel
STAR TOF	DOE MIE, China
STAR DAQ1000	DOE Cap Equip
PHENIX VTX	DOE MIE, Japan, France
PHENIX FVTX	DOE MIE
PHENIX MuTrg	NSF, Japan, Korea
STAR FGT	DOE Cap Equip
STAR HFT	DOE MIE

In Development phase

PHENIX FOCAL

STAR MDT

PHENIX EMCal Fee/Trig……

S&T 2008

- **Recommendations for S&T Review Report July 2008:**

  - ***BNL should strengthen collaboration management with experienced technical and project management expertise in order to implement the planned suite of detector upgrade projects. BNL should present progress at the 2009 RHIC S&T review.***

  - ***BNL should adopt a methodology to improve monitoring and consulting on detector upgrade projects sufficient to ensure progress on the needed aggressive timelines. BNL should document the methodology and present the same at the 2009 RHIC S&T review.***

At Last Year's S&T Review

S&T 2008

- STAR DAQ1000 completed 10% test
- STAR TOF was technically sound but behind schedule
- PHENIX HBD had significant technical problems
- PHENIX VTX had a number of technical challenges
- PHENIX MuTrg had budget problem
- PHENIX FVTX was just starting
- STAR FGT in R&D phase
- STAR HFT pending results from CD-0 review

S&T 2009

- DAQ1000 completely installed Successfully operated in Run-9
- TOF 75% installed. Remaining modules complete. Essentially done
- HBD repaired and reconfigured. Successfully ran in Run-9
- VTX successful beam test in Aug 2008. Technical problems overcome
- MuTrg rescoped with no loss in performance. Fabrication/installation far advanced
- FVTX continues to make progress
- FGT producing preproduction prototype
- HFT passed CD-0. Preparing for CD-1

New Upgrade Oversight Implemented

For projects other than DOE MIE projects

- **Annual project review by outside committee charged by BNL**
- **Quarterly budget, schedule technical documents reviewed by BNL with DOE participation**
- **Additional coordination with the management of the experiments. Monthly, in some cases weekly, reporting of upgrades progress to PHENIX/STAR management**
- **Quarterly summary report from BNL to DOE on all active upgrades**
- **Management Plan for each project approved by BNL Management and reviewed by DOE prior to start of construction**
  - **For projects <$2M Management Plan similar to DOE MIE 'Initial Packets' in quarterly report style.**

Other Project Management Improvements

- **BNL Project Planning experts Kerry Mirabella (CA-D) and Bob Ernst(Physics) provide consultation and assistance to BNL Management and upgrades project managers for all RHIC detector upgrades**
- **Project Office for STAR HFT being established at BNL. Kerry Mirabella, Flemming Videbaek (BNL), Hans Georg Riter (LBNL) leading the efforts, especially preparation for HFT CD-1 review Fall 2009**
- **BNL NPP Directorate is expanding pool of BNL project management experts in anticipation of a number of large NPP-based DOE MIE projects in the next few years.**
- **Improved communication between upgrades managers and BNL management resulting in better understanding of installation schedules, commissioning needs and coordination of first physics runs with RHIC multi-year operating schedule.**

Regular Reviews

Project	Date	Dates for Upcoming Reviews
STAR TOF	8/2008	8/2009 (Project Completion)
PHENIX VTX	6/2009	6/2010
PHENIX FVTX	11/2008	11/2009
STAR FGT	7/2008	Fall 2009
PHENIX MuTrg	9/2008	Fall 2009
STAR HFT	2/2008 **CD-0**	Sept/Oct 2009 **CD-1**
PHENIX FOCAL		Fall 2009 **

** **Initial Science and project scope review**

STAR TOF Review

STAR TOF Review Aug 11, 12 2008

Committee members: R. Betts (UIC), CY Chi (Columbia Univ), A. Drees (Stony Brook Univ), D. Lee (LANL), V. Radeka (BNL)

Some report highlights:

- ***The project team has made significant progress over the past year and should be commended. It is expected that at least 60 trays will be installed and commissioned for the FY 2009 RHIC run. (The number was actually 90)***
- ***The review committee fully expects that the complete complement of 120 trays will be installed and tested for first running in the FY 2010 RHIC run.***
- ***From the material presented, it is apparent that a good start has been made in preparing for physics analysis with the TOF detector.***
- ***The integration of the TOF detector system with the STAR detector has been well thought out and tested with the early installation and operation of a small number of TOF trays.***

STAR TOF Review Continued

Recommendations:

- ***The end game of the electronics production and testing needs to be planned. The Project managers should take steps to insure that there will be sufficient budget contingency reserved to deal with possible last minute cost increases.***
- ***The delivery schedule of the electronics needs to be watched carefully to stay ahead of the tray production. The milestones for the electronics board production should be set ahead of the tray production milestones to ensure that all the boards are delivered at least one month before the completion of the trays. Develop a plan for installation, testing and commissioning 65 TOF trays on a time scale consistent with RHIC Run 9.***
- ***Develop a plan for installation, testing and commissioning of the final full complement of TOF trays and all ancillary components on a time scale consistent with the FY 2010 RHIC run.***
- *We recommend that the Baseline Change Proposal, with Project Complete milestone in the 4th quarter of FY 2009, be adopted as presented.*

PHENIX Muon Trigger Upgrade Review

Review held Sept 25-26, 2008

Review Committee: Guiseppe Iaselli (Univ of Bari), Richard Milner (MIT), Paul O'Connor (BNL), Venetios Polychronakos (BNL), Werner Vogelsang (BNL), Xie Wei (Purdue Univ)

Overall the review went well. Some comments from review report:

- **"Based on the A_L projections it is expected that RHIC data for spin asymmetries in W production will have a significant impact in such an analysis, by placing tight constraints on the up and down quark and sea-quark distributions."**
- **"The rejection factor with or without the absorber will produce the W trigger rate to 0.2-1kHz which can be easily handled considering the bandwidth of PHENIX DAQ system (above 5kHz)"**
- **"The project is well managed and organized in sub-tasks led by competent and experienced individuals"**
- **"...the group has suitably fitted the RPC technology to the Phenix case also by extensively collaborating with some CMS member in the process of baseline definition and production/quality assurance protocols assessment. The engineering details for the chamber components production seems to be well understood and executive drawings are already available for the production."**

PHENIX Muon Trigger Upgrade Review

Excerpts of Recommendations:

- "**Studies should be carried out that investigate the impact that the RHIC W data are expected to have on our knowledge of the up and down quark and anti-quark distributions. The committee finds this to be important as it makes the scientific deliverable more precise.**"

- **"The background rate (and its nature) and the temperature at running condition which RPC3 will stand are not well known. These parameters are crucial for a satisfactory and ageing free long term detector operation. We therefore recommend to measure these parameters during the next RHIC run and extrapolate the values at the expected final machine luminosity and beam energy. Should these parameters exceed the acknowledge values for safe operation, action should be taken."**

- **"Initiate regular (perhaps quarterly) financial reporting to the PHENIX and BNL management for a better understanding of the project's progress within the context of the experiment"**

PHENIX VTX Review

Review held June 2,3 2009

Review committee: Tom Cormier(Wayne State Univ), Dave Lynn (BNL), Bernd Surrow(MIT), Rick VanBerg(Univ of Pennsylvania) and Sergio Zimmerman (LBNL).

Overall the committee was very positive about the progress the VTX project has made in the last 12 months.

Some draft report highlights:

- **"The committee is pleased to see that excellent progress has been made in dealing with the central technical issue that dominated the discussion at last year's review."**
- **"The Committee was very impressed by and pleased with the great progress made in many areas of the strip-pixel electronics over the past year. The revised ROC now seems to perform at the levels needed for the VTX…. The pixel detector electronics progress has also been gratifying ."**
- **"The VTX group together with the PHENIX Collaboration as a whole has completed a major step forward in addressing various outstanding simulation questions that have been pointed out during the last review."**

PHENIX VTX Review continued

Excerpts of recommendations:

- ***A clear plan should be put in place, documented, and reviewed, for the full installation and integration sequence of the VTX into PHENIX, including the final tests prior to installation, and the initial commissioning steps.***

- ***As soon as possible a test with two working pixel staves, and independently with two strip-pixel staves should be performed. With a lesser priority, a system test with staves of both types is desired.***

- ***The VTX group should perform a full hazard and risk analysis of the detector, identify all significant risks, and plan hardware-based interlocks (as opposed to the software systems used for normal monitoring and control) to safeguard the detector in all such circumstances.***

- ***The VTX group should complete a first draft of a complete power, grounding, and shielding plan within the next few months.***

FGT Management Plan- Initial Packet

WBS	Task Name	Material kS	Personnel kS	BNL transfer kS	Conting. %	Conting. kS	TEC, kS	Preops kS	TPC kS
1	FGT Project	591	900	119	29	410	1610		1610
1.1	Triple-GEM Detector	296	167		21	95	558		558
1.2	Front-end Electronics	92	258		23	80	430		430
1.3	DAQ	63	236		20	60	359		359
1.4	Infrastructure	20	62		24	20	102		102
1.5	Integration	120	177		52	155	452		452

- **List major hardware procurements.**

Item	Critical Path (Y/N)	Estimated Cost (kS)	Projected Procurement Date
GEM foils	Y	60	FY09 3Q
2D readout board	N	131	FY09 3Q
HV power supply	N	57	FY09 2Q
APV25 chips	N	50	FY09 1Q
APV modules	Y	84	FY09 2Q
DAQ readout boards	N	40	FY09 4Q
West support cone	Y	120	FY09 4Q

- **Budget breakdown**

WBS	Item	Baseline Total Cost (AYS)	Costed & Committed	Estimate To Complete (AYS)	Estimated Total Cost (AYS)	Available Contingency (AYS)	Available Contingency (% of Est to Comp)
1	FGT	1,416	81	1335	1416	411	29
1.1	Triple-GEM Detector	463	10	453	463	95	21
1.2	Front-End Electronics	350	71	279	350	80	23
1.3	DAQ	299	0	299	299	60	20
1.4	Infrastructure	82	0	82	82	20	24
1.5	Integration	297	0	297	297	155	52
1.7	BNL Overhead	119	0	119	119	0	0
1.8	Non-DOE contribution	-194	0			0	

FGT Management Plan- Initial Packet

Initial Packet of information:

Project Milestones

Milestone: WBS1.1.1.1
Description
Quarter section design complete
Projected completion date: FY08 4th Quarter
Critical Path: Critical path
Issues: None

Milestone: WBS1.1.1.4
Description:
2D readout board design complete
Projected completion date: FY09 2nd Quarter
Critical Path: Not a critical path item, but close
Issues: None

Milestone: WBS1.1.1.7
Description:
Full-size GEM foils tested and meet specifications
Projected completion date: FY09 1st Quarter
Critical Path: Critical path
Issues:
TechEtch has produced smaller foils, but has not yet produced full size foils.

Milestone: WBS1.1.1.9
Description:
Successful full quarter section test
Projected completion date: FY09 2nd Quarter
Critical Path: Critical path
Issues:
This is the first concrete deliverable of the project.

Milestone: WBS1.1.2.1
Description:
All GEM foils delivered by TechEtch that meet specifications
Projected completion date: FY09 3rd Quarter
Critical Path: Critical path
Issues:
Production quantities of large foils is the part with highest technical risk

Milestone: WBS1.1.6
Description:
All detector frames assembled and tested.
Projected completion date: FY10 1st Quarter
Critical Path: Critical path
Issues: None

Upgrades Project Status Table

Project	Start	End	TPC	Status
STAR DAQ1000	Q1FY06	Q4FY08	$1.8M	Condition-1
STAR TOF	Q1FY06	Q4FY09	$4.8M	Condition-1
PHENIX VTX	Q3FY07	Q4FY10	$4.7M	Condition-2
PHENIX FVTX	Q3FY08	Q3FY11	$4.9M	Condition-2
PHENIX MuTrg	Q1FY07	Q1FY11	$4.3M	Condition-2
PHENIX HBD	Q2FY05	Q4FY08	$1.2M	Condition-1
STAR FGT	Q4FY08	Q1FY11	$1.83M	Condition-2

Condition-1 = The project has no significant technical, cost or schedule issues. It is complete or will be completed meeting all technical, cost and schedule requirements.
Condition-2 = The project has one or more technical, cost or schedule issues. Correction action has been taken and a successful completion is expected.

Condition-3 = The project has one or more technical, cost or schedule issues. Correction action has been identified but there is a possibility that a technical, cost or schedule goal will not be met.
Condition-4 = The project has one or more technical, cost or schedule issues. Correction action has been identified but there is a possibility that a technical, cost or schedule goal will not be met.

Regular Reporting of Upgrade Detector Progress to Experiment Management

PHENIX Detector Council Meeting June 10, 2009

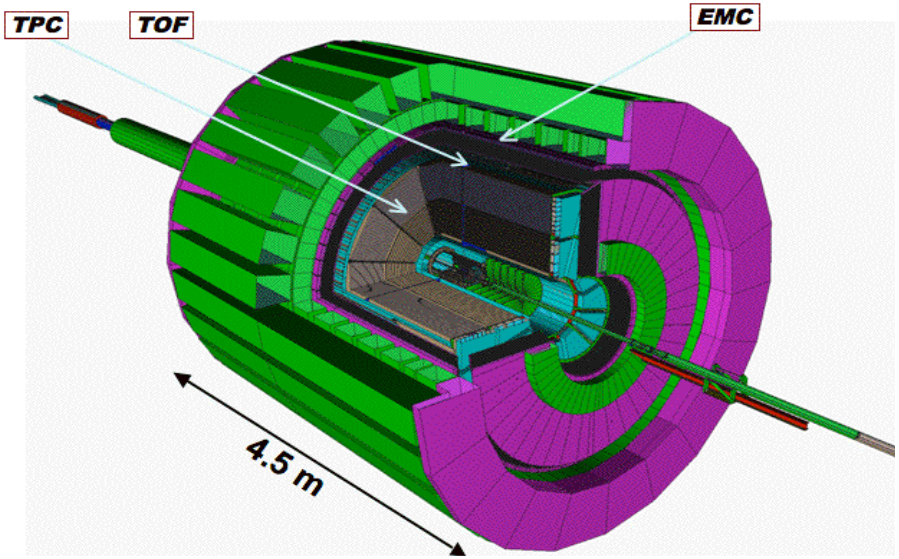
Agenda:

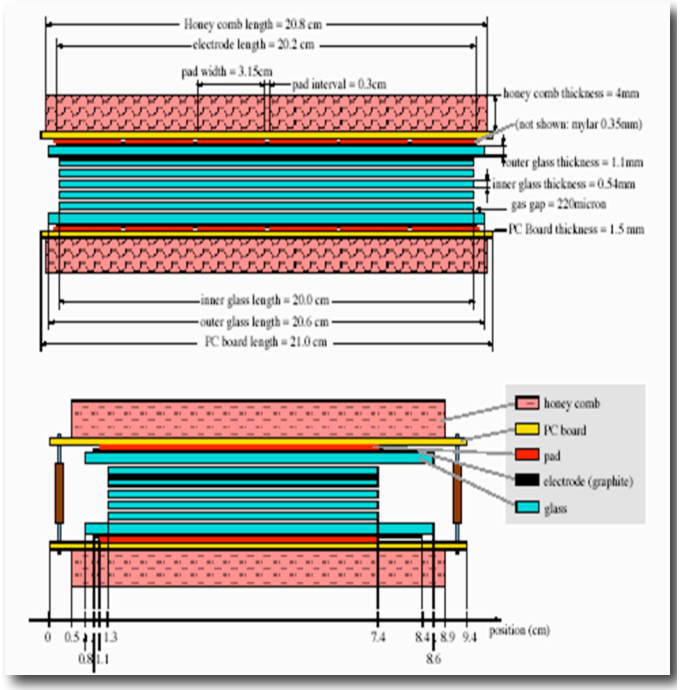
9:00	PHENIX News/Overview
9:20	Plans for 2009 Shutdown
9:40	Status of Run-9
10:00	VTX Update
10:20	FVTX Status
10:40	Break
11:00	MuTrig RPC Update
11:15	MuTrg Fee Status
11:30	HBD Shutdown Plans
11:45	FOCAL Status
12:00	Cosmic Ray Run in 2009
12:15	Status of Data Production

Technical Progress of Upgrade Detectors

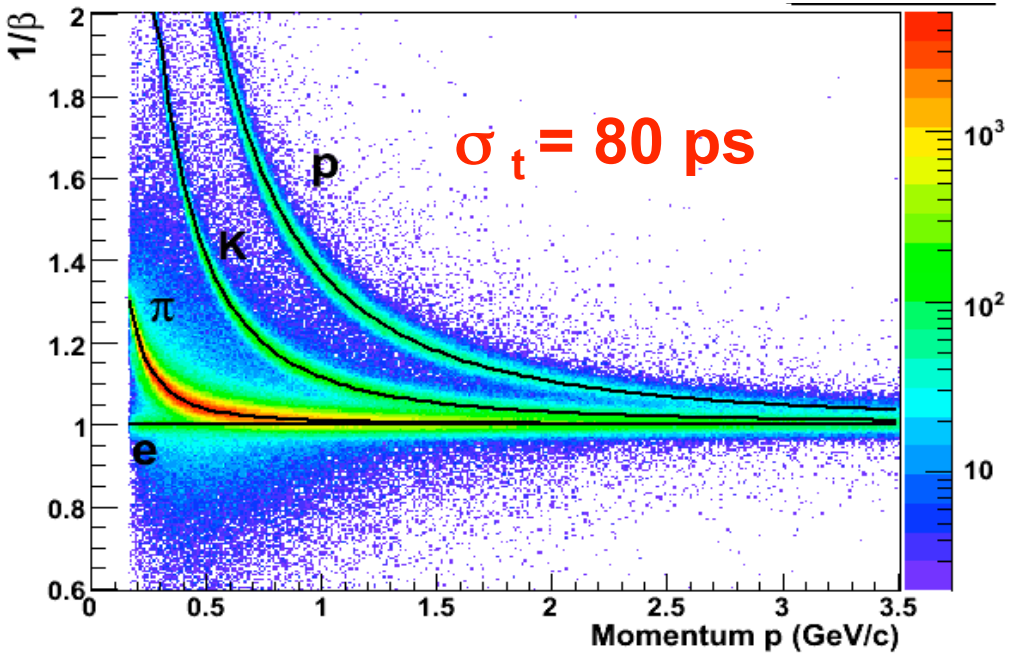
Particle ID Upgrades

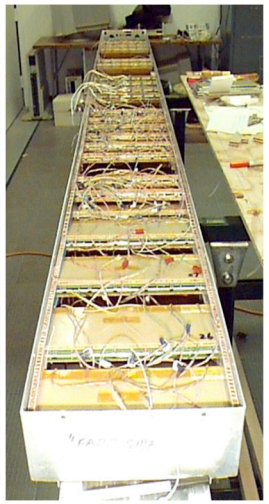
STAR Time of Flight



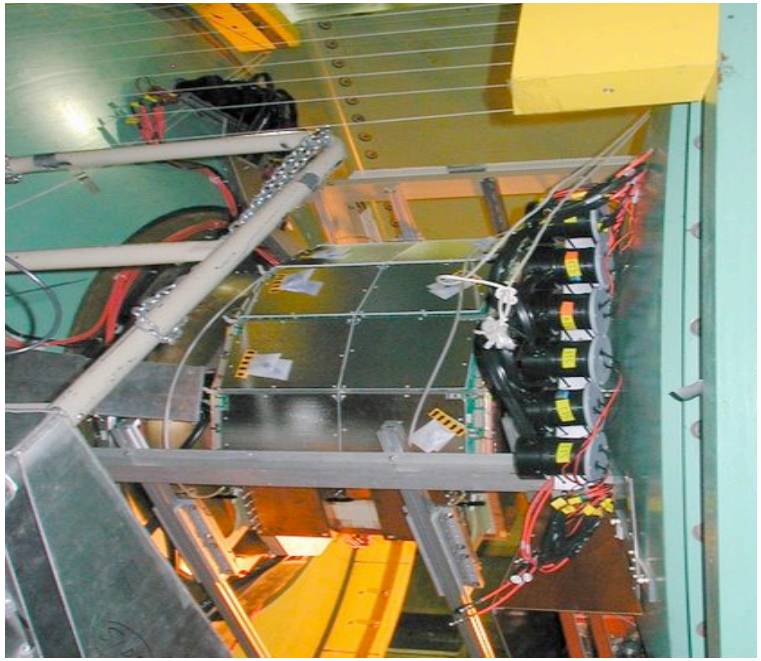


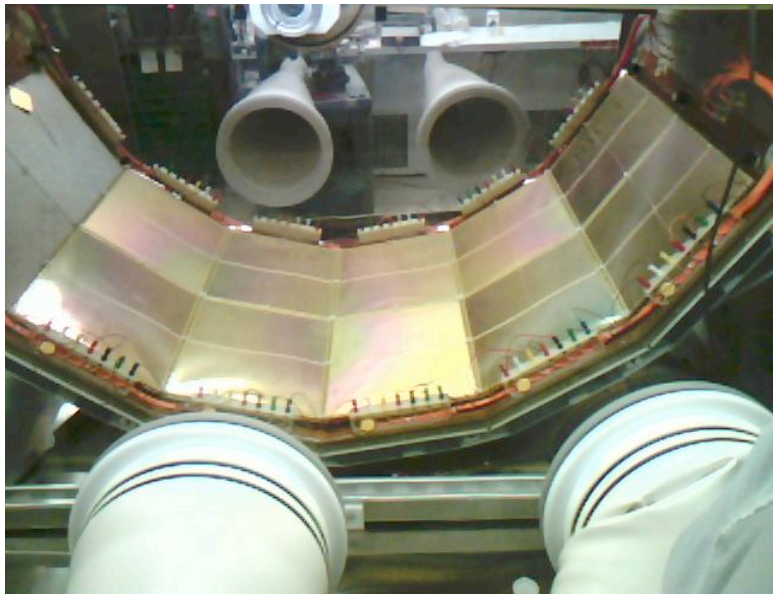
Results from Run-9 w/ >75% installed

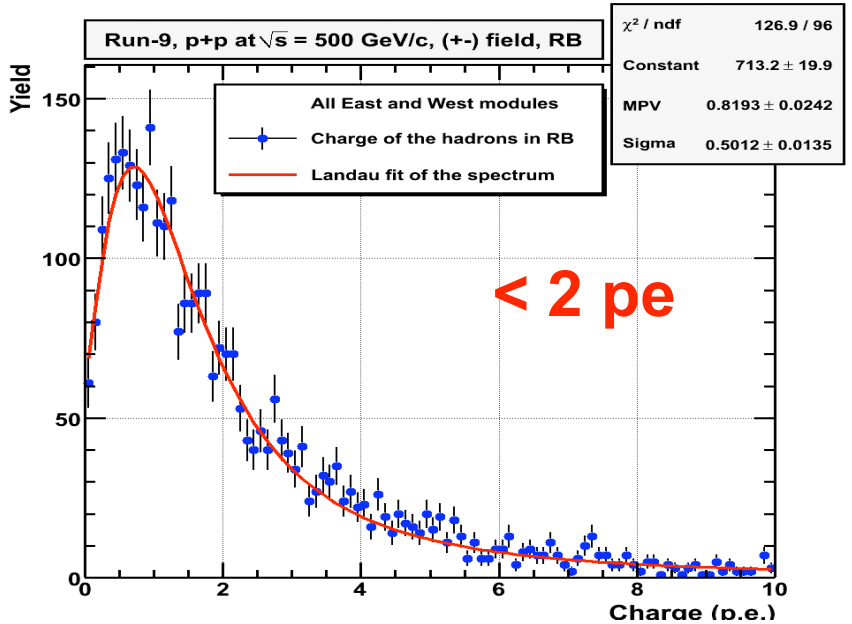




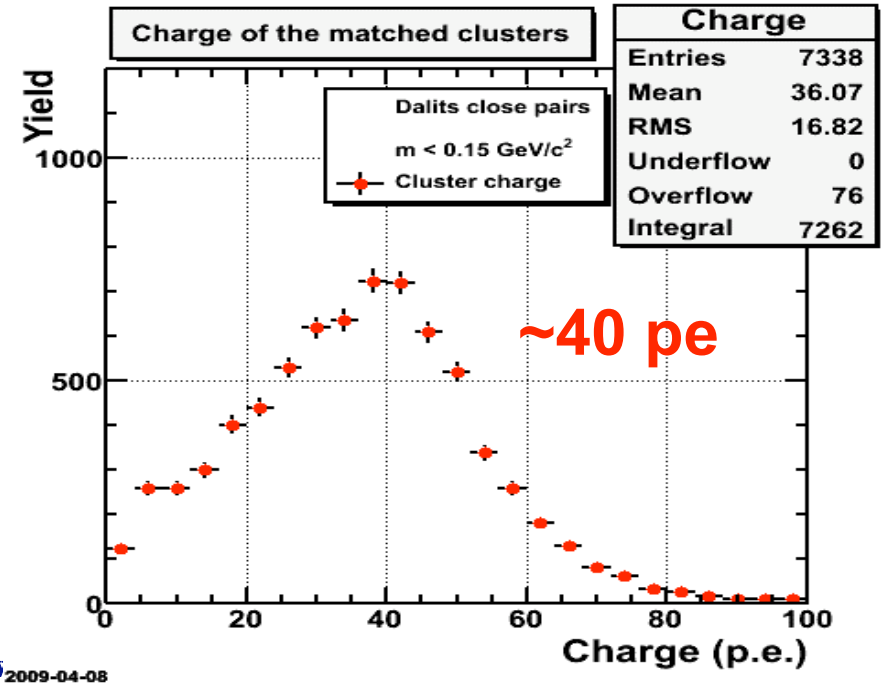
PHENIX Hadron Blind Detector





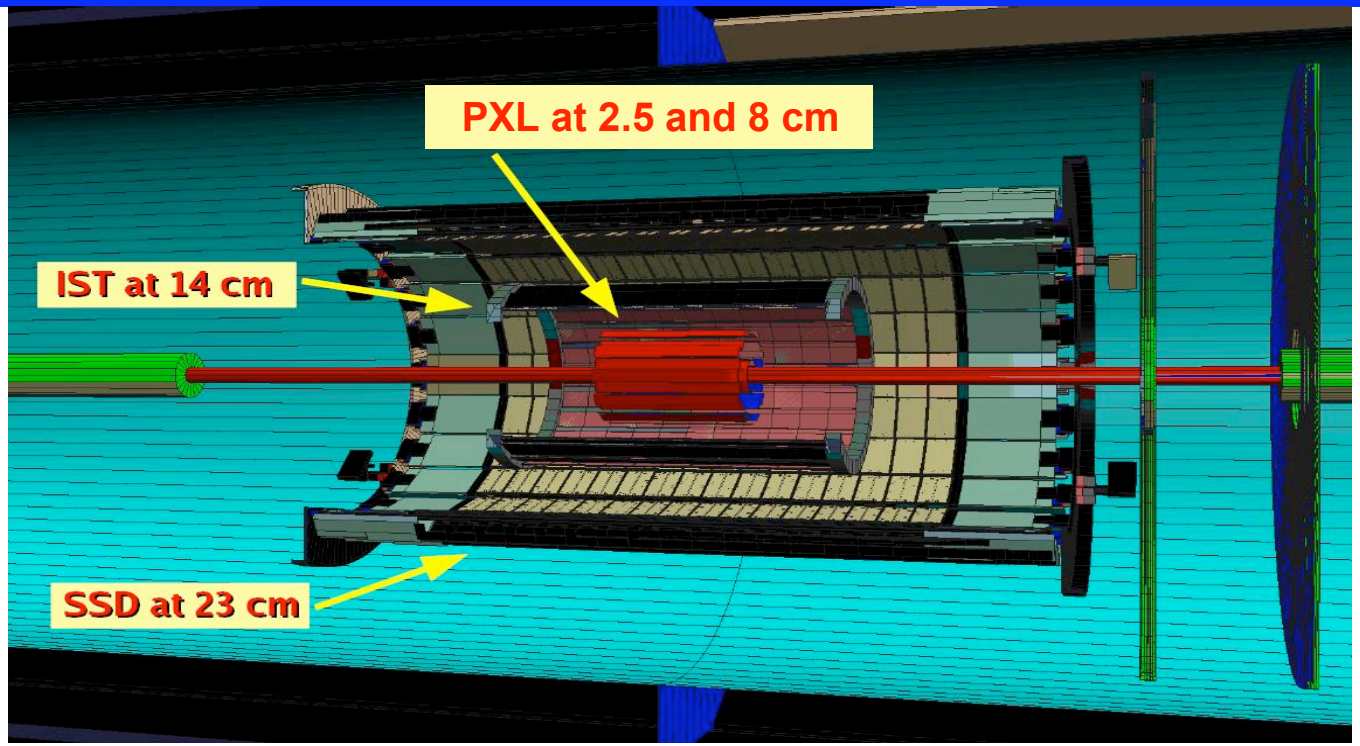


CF4 gas



Silicon Vertex Detectors

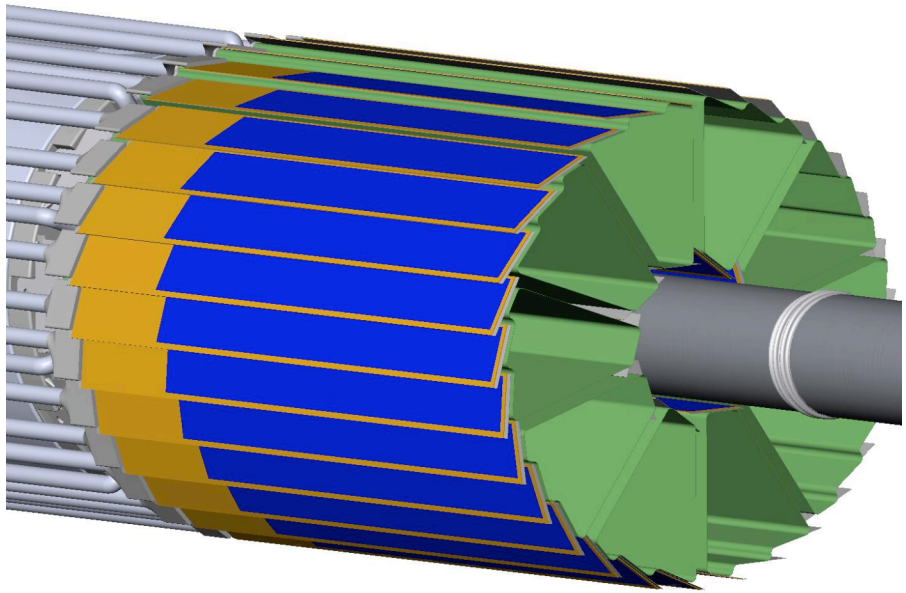
STAR Heavy Flavor Tracker



HFT: 2 layers of Si pixel, 1 layer Si pad, 1 layer Si strip

- Pixel layers are very thin (< few hundred micron) active pixel sensors
- Goal is to measure open heavy quark through DCA
- Direct D meson reconstruction
- B measurement through J/psi w/ displaced vertex
- Contributes to many other physics measurements

HFT Pixel Layers



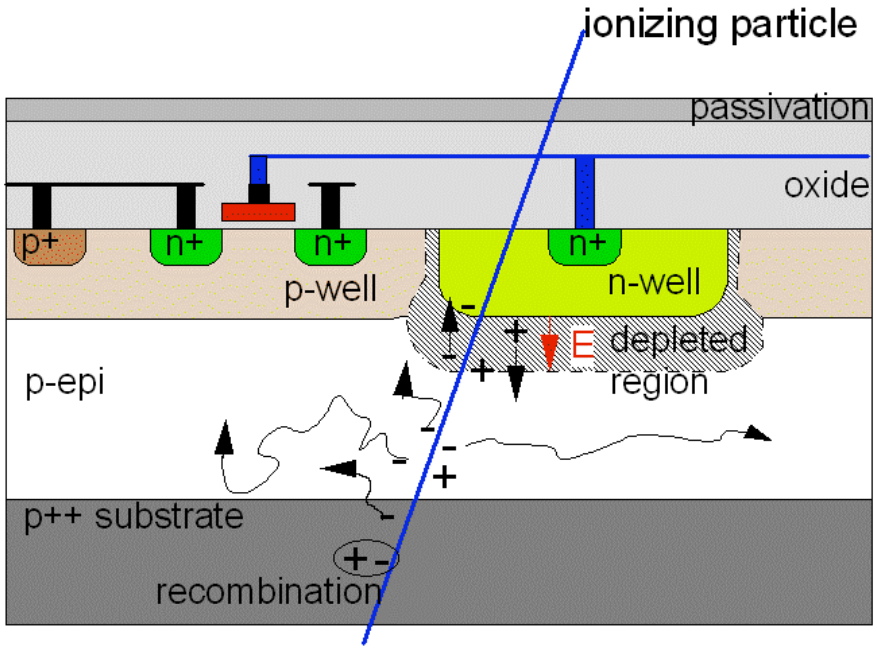
Some Specifications:

- 2 layers of 18x18 μm pixels at 2.5 and 8 cm radius, 20 cm long
- Very low material budget to limit multiple scattering
- Data reduction and formatting on chip
- Rapid insertion and removal
- Precision positioning
- Air cooling
- Ongoing APS technology R&D with Strasburg
- RHIC luminosities needs 'fast' detector w/ better than 200 μsec integration time.
- Efficiencies degrade with 'pile-up' within sample time

HFT Active Pixel Sensors

pixel chips (MAPS) produced by

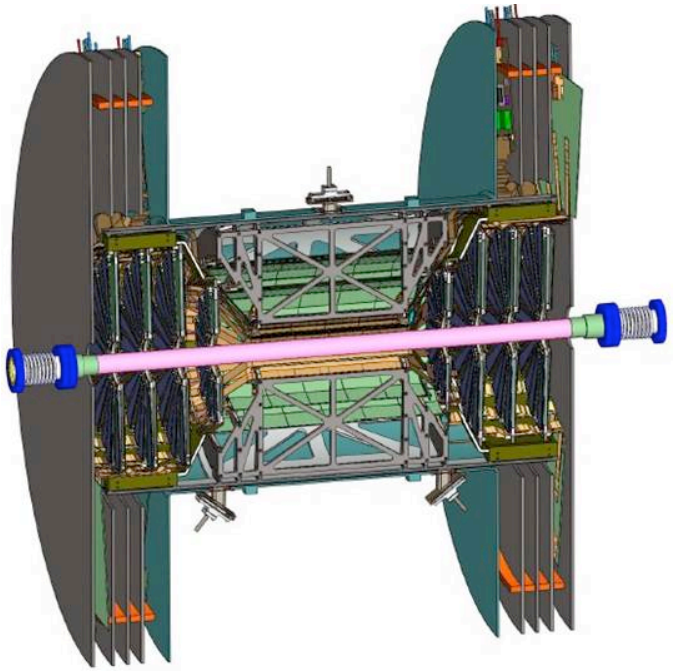
IReS/LEPSI → IPHC (Strasburg)



Properties:

- Signal created in low-doped epitaxial layer (typically ~10-15 μm)
- Sensor and signal processing integrated in the same silicon wafer
- Standard commercial CMOS technology

PHENIX Silicon Vertex Detector



Silicon Detector composed of:

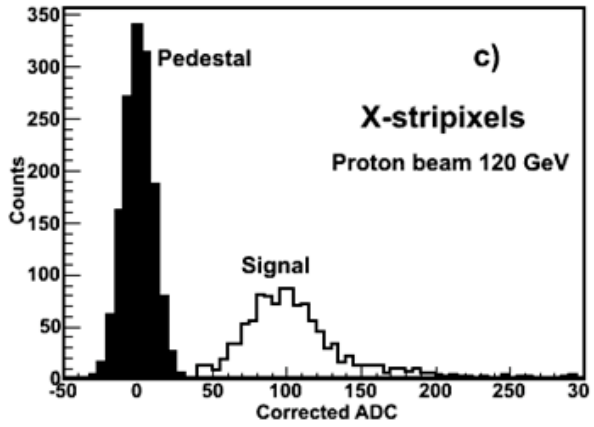
4 layer barrel, 2 x 4 layer endcaps

Barrel VTX (-1.5 < η < 1.5)

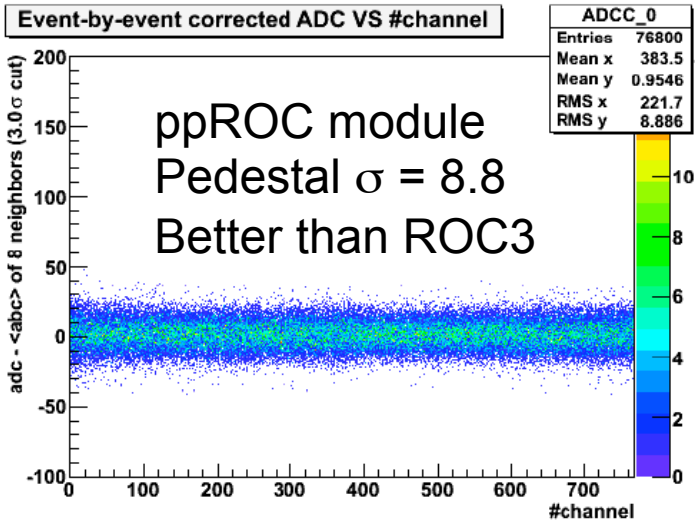
- **2 pixel layers (ALICE sensors and electronics)**
- **2 stripixel layers. Unique charge-sharing design**
  - **SVX4 electronics**

Endcap FVTX (1.0 < | η | < 2.5)

- **Mini Si strips (modified BTeV electronics)**
- **Optimized for open heavy quark measurements using DCA.**
- **B measured through J/psi w/ displaced vertex**



MIP peak: 98.6
Pedestal σ: 9.6
S/N: 10.3
Efficiency: 99.5%



PHENIX Silicon Vertex Detector

120 GeV proton beam at FNAL (T984)

- **Hit residuals from tracks obtained from the stripixel detectors:**

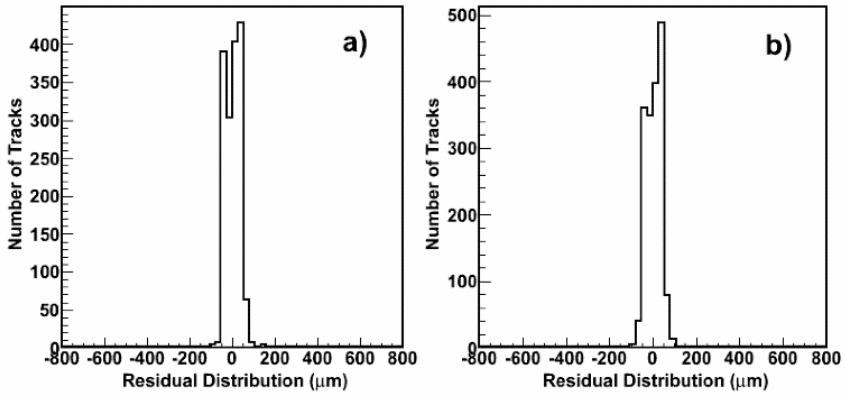
in X stripixel:

0.42 x 80 (μm) = 33.6 (μm)

in U stripixel:

0.44 x 80 (μm) = 35.2 (μm)

from the RMS values.



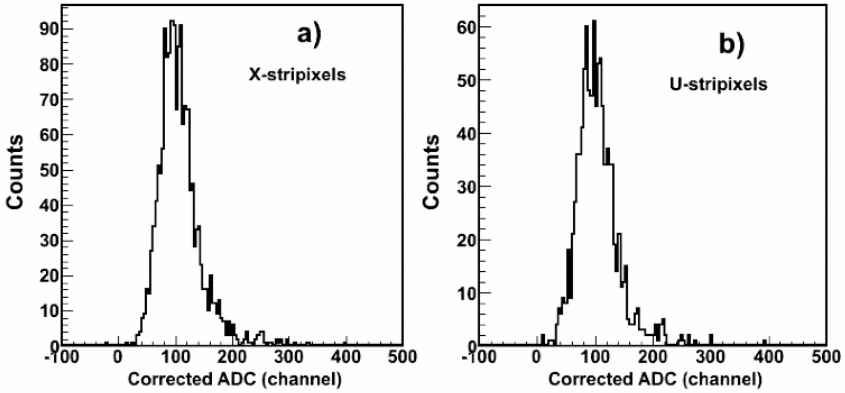
- **Tracking efficiency using the stripixel detector (middle layer)**

in X stripixel: 99.5 ± 0.2%

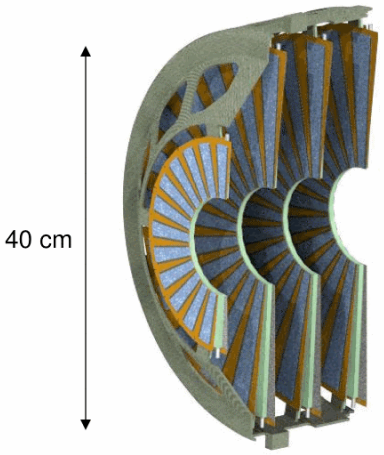
in U stripixel: 98.9 ± 0.2%

Tracking efficiencies in

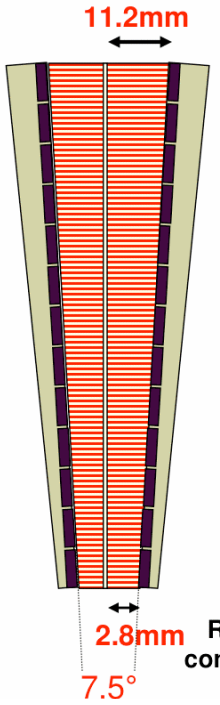
both stripixels are very good

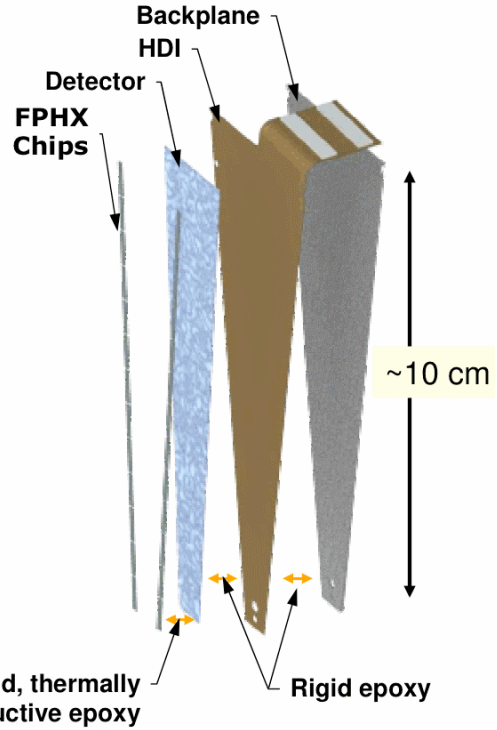


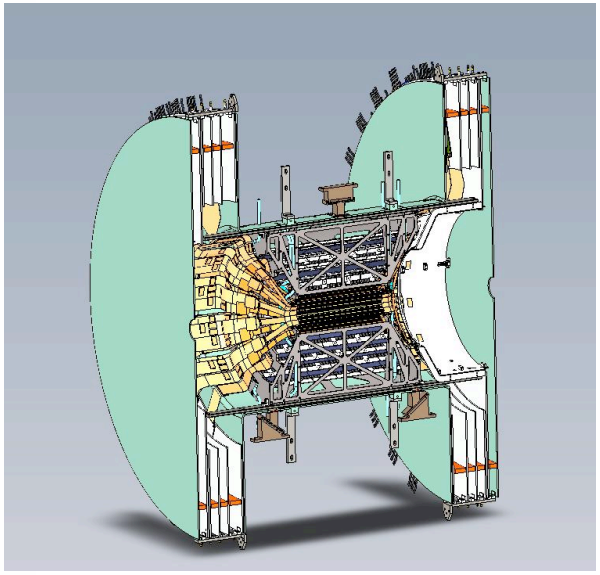
PHENIX Forward Silicon Vertex Detector



- 4 disks / side
- 48 wedges/disk
- 75 µm strips,
- 2.8-11.2 mm long
- 1664 strips/column
- 1.1M channels total
- Readout with FPHX chip

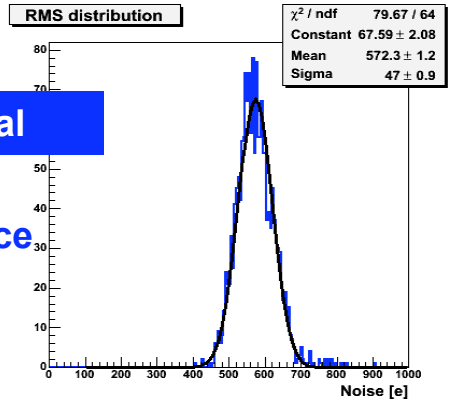






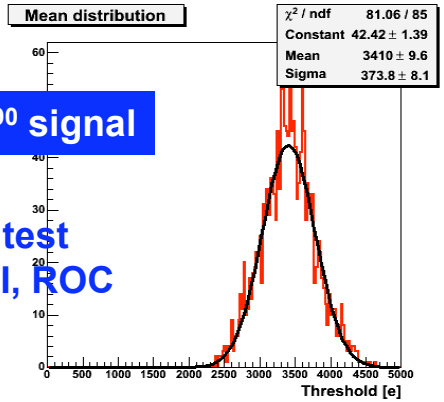
Sensor pedestal signal

Expected noise performance



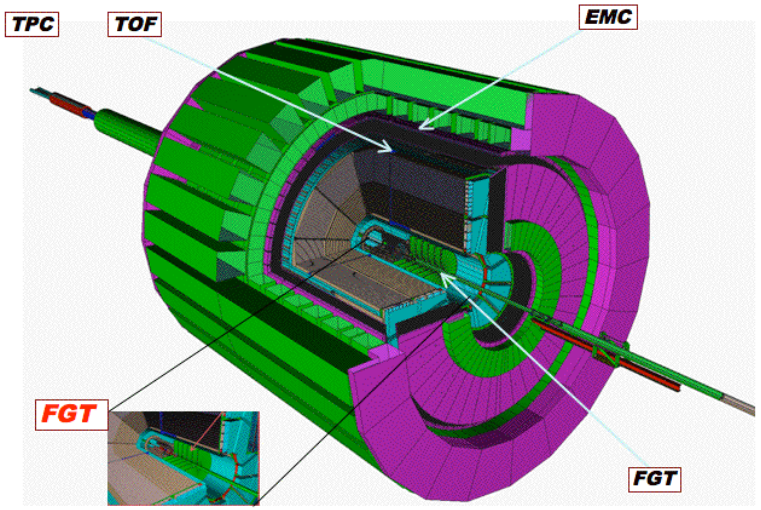
Sensor Sr^{90} signal

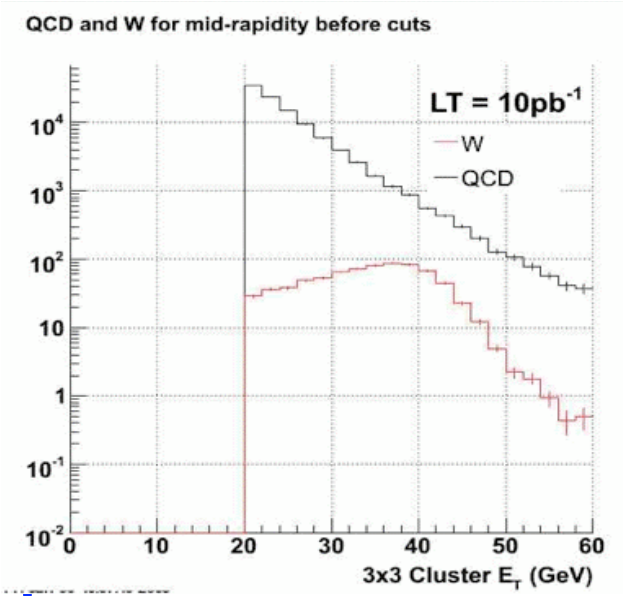
Prototype chain test
Sensor,ASIC HDI, ROC



Detectors for the W program

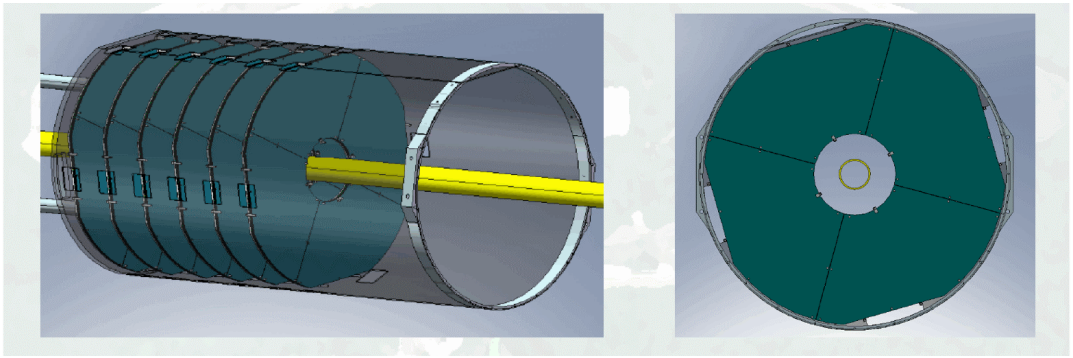
STAR Forward GEM Tracker

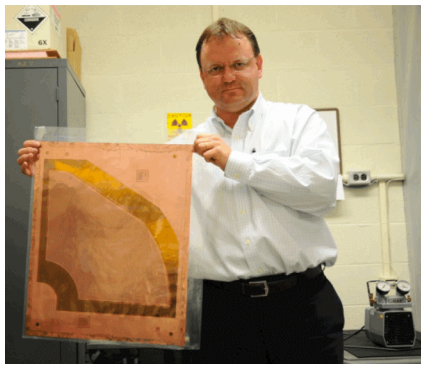




W Measured through W→ e ν channel

- **Forward EM Calorimeter provide required energy resolution**
- **GEM needed for sign determination**
- **Test beam of FGT prototype shows required resolution**





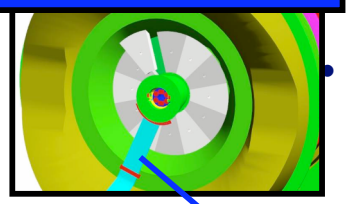
PHENIX Muon Trigger

The Muon Trigger Upgrade consists of:

- **4 Stations of Resistive Plate Chambers**
  - **2 North, 2 South**
- **Addition of LVL1 electronics to MuTracker**
  - **St2, St3 North and St2, St3 South**

Increases LVL1 rejection by ~2 orders of magnitude

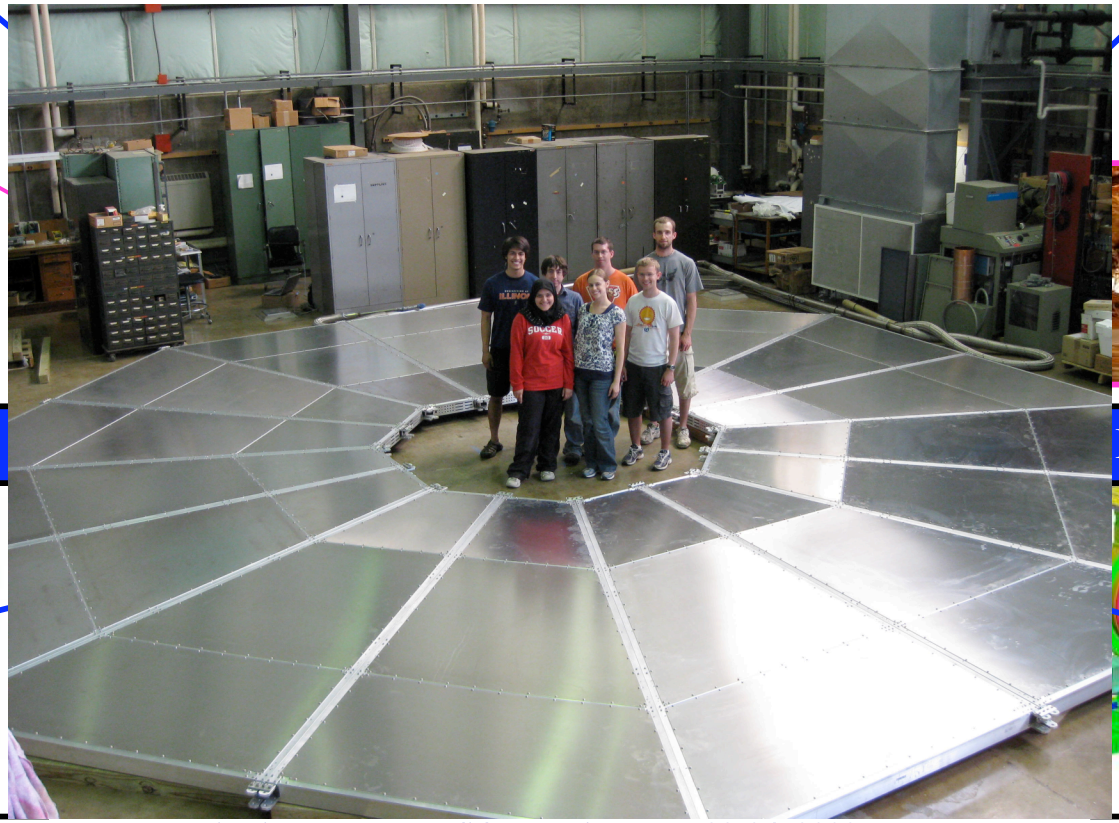
MuTrig Station 1



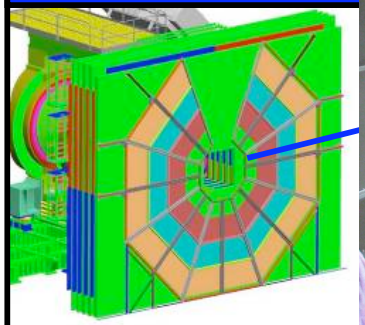
MuTrig Station 1

MuTrig Fee

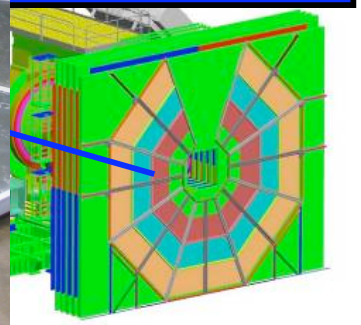
MuTrig Fee



MuTrig Station 3

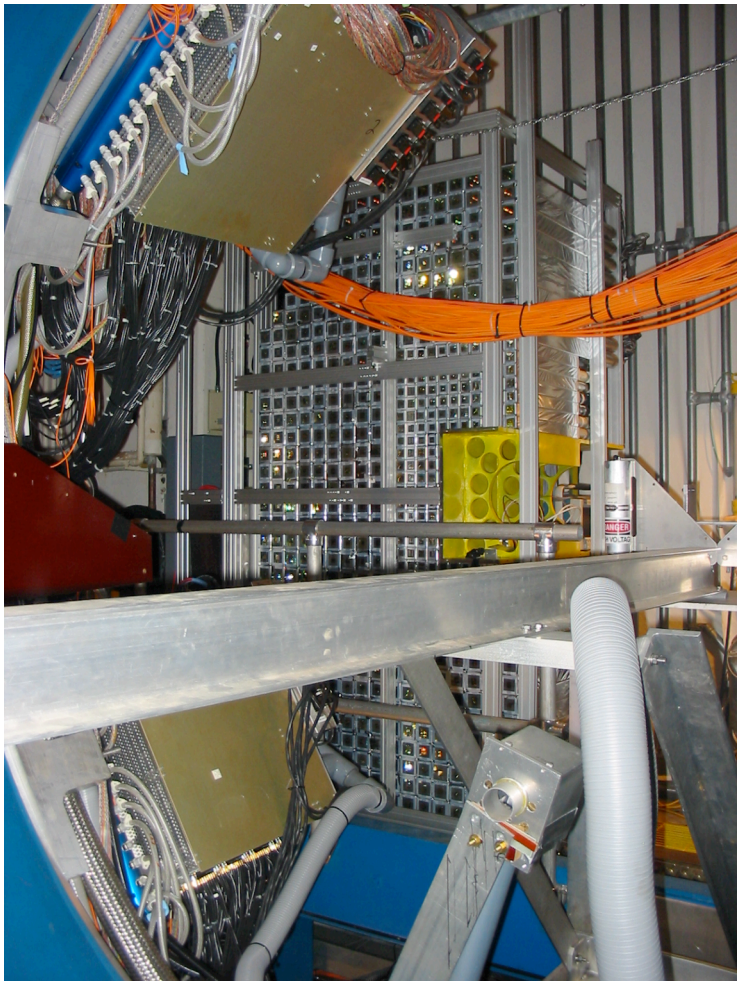


MuTrig Station 3

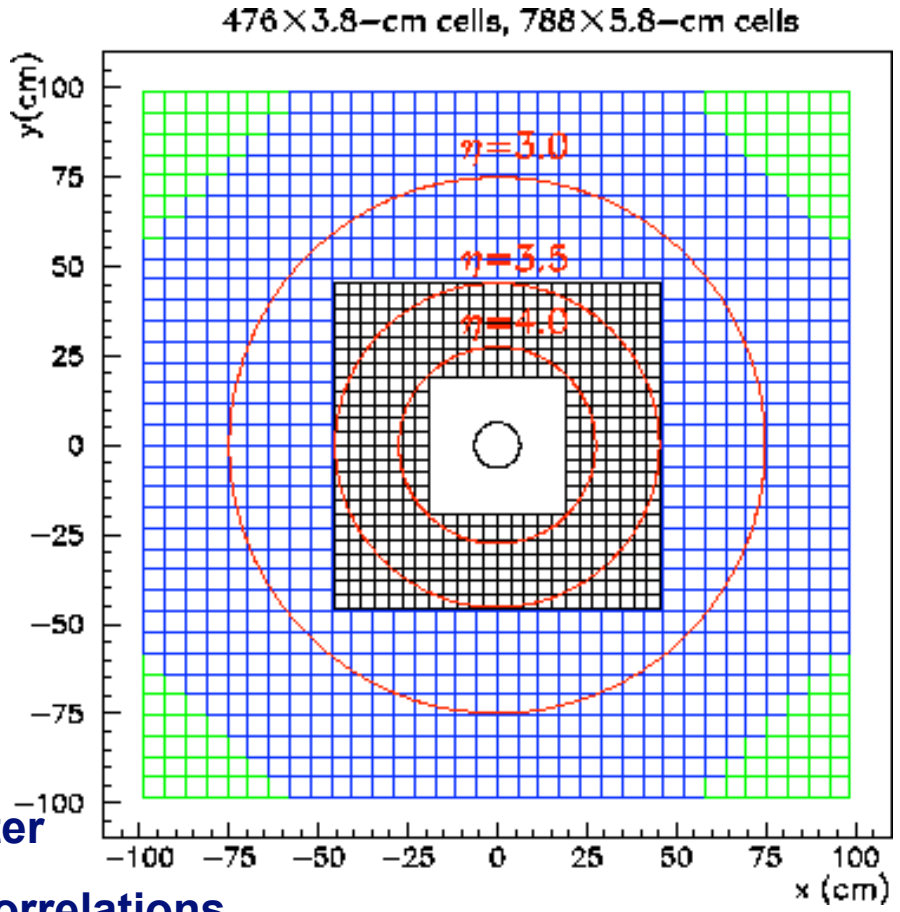


Forward Calorimetry

STAR Forward Meson Spectrometer (FMS)



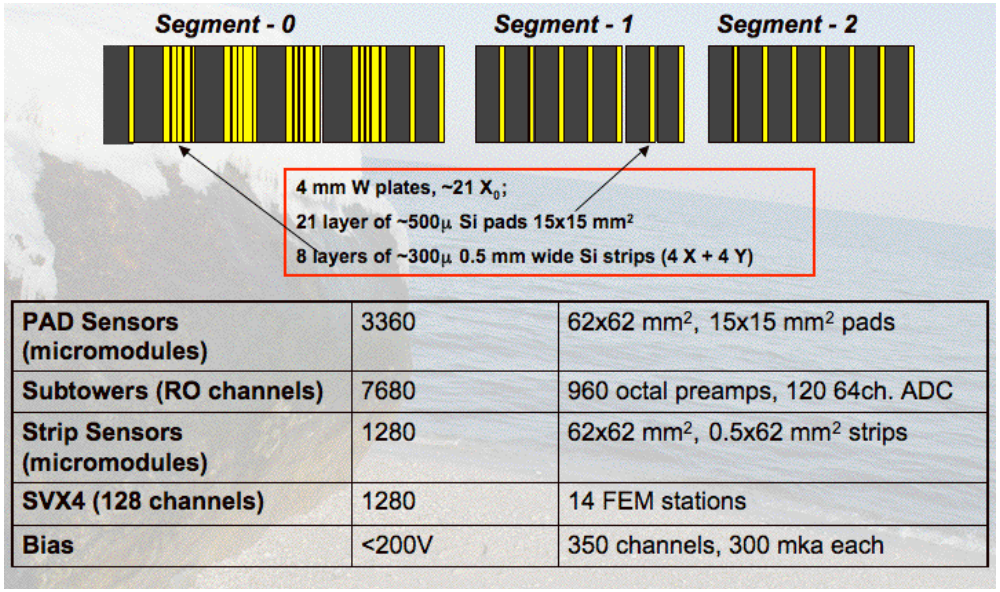
Schematic of the FMS as seen from the interaction point. The small-cell inner calorimeter has 476 detectors and the large cell outer calorimeter has 788 detectors.



Coverage $2.5 < \eta < 4.0$ for Pb-glass calorimeter

- **Gluon saturation effects, ΔG at low x, γ-jet correlations**

PHENIX Forward Calorimeter



PAD Sensors (micromodules)	3360	62x62 mm², 15x15 mm² pads
Subtowers (RO channels)	7680	960 octal preamps, 120 64ch. ADC
Strip Sensors (micromodules)	1280	62x62 mm², 0.5x62 mm² strips
SVX4 (128 channels)	1280	14 FEM stations
Bias	<200V	350 channels, 300 mka each

Forward Calorimeter **Silicon pads +silicon strips +tungsten**

- Provides calorimeter coverage in the range $1.5 < \eta < 3.0$
  - No calorimeter coverage in this pseudorapidity range in PHENIX
  - Shadows both the Muon spectrometer and silicon VTX endcaps
- 3 longitudinal segments including preshower for γ / π^0 separation
  - 21 Xo
  - $\Delta E/E \sim 23\%/E^{1/2}$
- Low x measurements for ΔG, gluon saturation
- Two particle correlations with γ -jet

Summary of Recent Upgrades Progress

- **STAR DAQ1000 was commissioned and operated successfully in Run-9**
  - DAQ Operated at 500 Hz, 95% live in Run-9
- **STAR TOF 75% installed and took data in Run-9. Timing performance meets spec σ_t < 80 ps**
  - Remainder to be installed in 2009 shutdown prior to Run-10
- **STAR HFT passed CD-0. CD-1 review to be scheduled for Fall 2009**
  - Project team has been established
- **STAR FGT GEM preproduction under construction**
- **PHENIX HBD 500 GeV run was a success. Ready for HI run in Run-10**
  - HBD had stable HV operation throughout Run-9. No luminosity effect.
  - No evidence of performance degradation over time
  - Good #PE's for each electron (~20)
- **PHENIX VTX Stripixel Fee chain test successful and complete.**
  - Stripixel production Fee started (ROC, RCC..)
  - Fab also started for Pixel Fee, all mech parts, assembly equip.
- **PHENIX FVTX wedge test with prototype Sensor, ASIC, HDI, ROC underway**
  - Prototype tests nearly done. Next preproduction orders
- **PHENIX MuTrg Fee completely installed and tested in MMN in Run-9**
  - Remaining Fee fab complete. Installation for MMS starts within 4 weeks.
  - RPC all St3 parts at BNL. St1 bakelite complete.
  - St3 installation in MMN this summer/fall
- **PHENIX DAQTRIG2010, DCM II design ongoing at Nevis**

Summary

- **PHENIX and STAR are in the middle of a multi-year upgrades program which will expand the experiments' physics capabilities in parallel with the RHIC accelerator's luminosity improvements**
  - **10+ new subsystems**
  - **~ $50M total cost including R&D**
  - **Multiple funding sources with DOE being the largest**
- **A number of these upgrades have successfully been completed in the last year or are about to finish**
  - **STAR DAQ1000, STAR TOF, PHENIX HBD**
- **New project methodologies and personnel have been put in place to improve management of these upgrades**
  - **For non-DOE MIE's Annual Reviews, Quarterly Reports, Management Plans, additional project experts now work with to BNL team managing these projects.**
- **Overall improvement in technical performance, schedules and budgets across all of the upgrade projects, though certain concerns still remain.**
- **A lot of work ahead before all projects are complete and taking data. Expect new oversight structure will greatly improve successful outcomes of the upgrades project.**